CHARLES DARWIN UNIVERSITY

Family Name	
Given Names	
Student Number	
Teaching Period	Semester 1, 2017

FINAL EXAMINATION	DURATION
ENG424 – Power Engineering	Reading Time: **10** minutes Writing Time: **180** minutes

INSTRUCTIONS TO CANDIDATES

EXAM CONDITIONS

<u>You may begin writing from the commencement of the examination session.</u> The reading time indicated above is provided as a guide only.

This is a CLOSED BOOK examination

Any non-programmable calculator is permitted

No handwritten notes are permitted

No dictionaries are permitted

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
none	1 x 20 Page Book 1 x Scrap Paper

THIS EXAMINATION IS PRINTED

DOUBLE-SIDED.

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NOTE: In order to explain your work, draw suitable diagrams whenever possible. This applies to all questions in this exam.

QUESTION 1 (10 marks)

Briefly answer the following questions. One or two sentences each will suffice. Each question is worth 1 mark.

Q1.1 How does the voltage generated in a circuit relate to the Flux linkage? Use plain English, not equations.

Q1.2 What is the difference between a power station and a power substation?

Q1.3 What is a bus in electrical power system?

Q1.4 What is an infinite bus?

Q1.5 What is the difference between a power circuit breaker and an isolator?

Q1.6 What is the difference between equipment grounding and system grounding?

Q1.7 Consider a set of five numbers: 1, 2, 3, 4 and 5. Determine their rms value.

Q1.8 We talk a lot about equivalent circuits of machines e.g. transformers, synchronous machines etc. What is an equivalent circuit?

Q1.9 A three phase two winding transformer is connected to a bus via a circuit breaker and isolators on both sides. Draw a single line diagram to show these connected items.

Q1.10 A series circuit consisting of 8 ohms of resistance and 6 ohms inductive reactance (i.e. $8 + j6 = 10 \angle 36.9^0$ ohms) is supplied from a voltage source of 240 volts line to neutral. Draw a phasor diagram showing the current and all the voltage drops in the circuit.

QUESTION 2 (10 marks)

A 200 kVA, 480 volt, 50 Hz, star connected synchronous generator with a rated field current of 5 amps was tested at rated speed and the following data were taken:

1. The open circuit terminal voltage of the generator was 540 volts at rated field current.
2. The short circuit line current was 300 amps at rated field current.
3. With the machine at standstill, a dc voltage of 10 volts was applied between two of the generator terminals, a current of 25 amps was measured.

Determine the values of the armature reactance and the synchronous reactance for the generator equivalent circuit.

QUESTION 3 (10 marks)

A 50 hp, 250 volt, 1200 rpm dc shunt motor has an armature resistance of 0.06 ohms. Its field circuit has a resistance of 50 ohms. When rated voltage is applied, the motor attains a no-load speed of 1,200 rpm. Determine the speed of the motor when the motor draws a line current of 300 amps in order to drive the load imposed on its shaft. You may consider no-load armature current to be negligible.

QUESTION 4 (10 marks)

A 480 volt, 60 Hz, 50 hp, three phase induction motor draws 60 amps at 0.85 power factor lagging. The stator copper losses are 2 kW and the rotor copper losses are 700 watts. The friction and windage losses are 600 watts, the core losses are 1800 watts.

Q4.1 Determine the airgap power

Q4.2 Determine the power converted into mechanical form.

Q4.3 Determine the net output power.

Q4.4 Determine the efficiency of the motor.

QUESTION 5 (10 marks)

Answer the following questions in brief.

Q5.1 What is an instrument transformer? How is it different from a power transformer?

(2 mark)

Q5.2 Suppose the following situation. In order to supply a three phase load of 300 kVA, you ordered three single phase transformers rated 100 kVA each. When they arrived, you noticed to your surprise that one of the transformers got damaged during transformation. It will take a month to return the damaged unit and get it back after repair. What can you do with the two units? Explain.

(4 marks)

Q5.3 A three phase transformer rated 50 MVA, 138/13.8 kV, 10% impedance is to be used in your 132/11 kV system. For your calculations, you have chosen a base power of 100 MVA and 11 kV at the 11 kV bus. What per unit impedance will you use for this transformer?

(2 marks)

Q5.4 Power utilities around the world generate ac voltage in sinusoidal form. Why?

(2 marks)

FORMULAS

(Symbols have their usual meanings in the context of the particular formula)

MAGNETIC CIRCUITS: $L = \lambda / i = N^2/\Re = \mu N^2 A/d$; $\quad Ni = \sum H\ell = \varphi \Re$;

$B = \mu H = \mu Ni/\ell$; $\quad \mu = \mu_r \mu_0$; $\quad \Re = \ell/\mu A$

TRANSFORMERS: $\dfrac{V_1}{V_2} = \dfrac{I_2}{I_I} = \dfrac{N_1}{N_2}$; $Z_1 = \left(\dfrac{N_1}{N_2}\right)^2 Z_2$; $R_c^{'} = \dfrac{V_{oc}}{I_{oc}\cos\theta}$; $X_m = \dfrac{V_{oc}}{I_{oc}\sin\theta}$;

$\cos\theta = \dfrac{P_{oc}}{V_{oc} I_{oc}}$; $\eta = \dfrac{V_2^{'} I_2^{'} \cos\theta}{V_2^{'} I_2^{'} \cos\theta + P_c + R_{eq}^{'} (I_2^{'})^2} \times 100\%$

$$\eta_{AD} = \frac{\text{Energy output over 24 hours}}{\text{Energy input over 24 hours}} \times 100\%$$

$$\text{Regulation} = \frac{\text{No load voltage} - \text{Full load voltage}}{\text{Full load voltage}} \times 100$$

INDUCTION MACHINES: (Torque and power are given on a per phase basis)

$n = 120\dfrac{f}{p}$; $\quad s = \dfrac{(n_s - n)}{n_s}$; $\quad f_2 = sf_1$; $\quad E_{rms} = 4.44 f\, N_{ph}\, \varphi_p\, K_w$

$V_{th} = \dfrac{X_m}{\sqrt{R_1^2 + (X_1 + X_m)^2}} V_1$; $\quad R_{th} \cong \left(\dfrac{X_m}{X_1 + X_m}\right)^2 R_1 \quad X_{th} \cong X_1$

$P_{mech} = T_{mech}\, \omega_{mech} = (1-s) P_{air\_gap}$; $\quad$ Ideal Efficiency = 1-s;

$T_{mech} = \dfrac{1}{\omega_s} I_2'^2 \dfrac{R_2'}{s} = \dfrac{1}{\omega_s} \dfrac{V_{th}^2}{(R_{th} + R_2'/s)^2 + (X_{th} + X_2')^2} \dfrac{R_2'}{s}$; $\quad P_{air\_gap} = I_2'^2 \dfrac{R_2'}{s}$

$s_{Tmax} = \dfrac{R_2'}{\sqrt{R_{th}^2 + (X_{th} + X_2')^2}}$; $\quad T_{max} = \dfrac{1}{2\omega_s} \dfrac{V_{th}^2}{R_{th} + \sqrt{R_{th}^2 + (X_{th} + X_2')^2}}$

DC MACHINES: $K_a = \dfrac{Zp}{2\pi a}$; $E_a = K_a \varphi \omega$; $T = K_a \varphi I_a$; $P_{out} = E_a I_a = T\omega$; La=p wound.

ALTERNATORS: $E_f \propto I_f \quad E_f = V_t + jI_a X_s \quad E_f = V_t + I_a R_a + jI_d X_d + jI_q X_q$

$P = \dfrac{|V_t||E_f|}{|Z_s|}\cos(\theta_s - \delta) - \dfrac{|V_t|^2}{|Z_s|}\cos\theta_s \qquad Q = \dfrac{|V_t||E_f|}{|Z_s|}\sin(\theta_s - \delta) - \dfrac{|V_t|^2}{|Z_s|}\cos\theta_s$

$E_f = V_t \cos\delta \pm I_d X_d$, $\; I_a = |I_q| - j|I_d|$ and $V_t = |V_t| \angle{-\delta}$

$$P = \frac{|V_t||E_f|}{|X_d|}\sin\delta + \frac{|V_t|^2 (X_d - X_q)}{2X_d X_q}\sin 2\delta \qquad Q = \frac{|V_t||E_f|}{|X_d|}\cos\delta + |V_t|^2 \left| \frac{\sin^2\delta}{X_q} + \frac{\cos^2\delta}{X_d} \right|$$

OTHERS: $S = \sqrt{3}\, V_L\, I_L$; $Z_{pu} = \dfrac{Z_{ohm}}{Z_{base}}$; $Z_{base} = \dfrac{(kV_{base})^2}{MVA_{base}}$;

$S_{pu} = kV_{pu}\, kA_{pu}$ (no √**3**); $kA_{pu} = \dfrac{MVA_b}{\sqrt{3}\ kVA_b}$; $Z_{pu2} = Z_{pu1} \times \dfrac{S_{base2}}{S_{base1}} \times \dfrac{kV_{base1}^2}{kV_{base2}^2}$